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HETA 2000-0316-2811
Material Sciences Corporation
Pinole Point Steel
Richmond, California

Daniel J. Habes

PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Daniel J. Habes of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Desktop publishing was performed by Robin Smith. Review and preparation for printing were performed by Penny Arthur.

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Highlights of the NIOSH Health Hazard Evaluation

Ergonomics Evaluation of Zinc Pot Skimming

NIOSH was asked to determine if the manual skimming of dross from the zinc pot of a galvanizing operation presented a hazard to workers at the Material Sciences Corporation Pinole Point Steel Plant.

What NIOSH Did

Measured the weight of one spoonful of dross.

Measured the length and size of tools and other items found at the zinc pot.

Videotaped workers while they did the job to estimate how much reaching and bending is done.

What NIOSH Found

Lifting the spoon out of the zinc bath places high forces on the joints of the body.

The spoon loaded with dross is too heavy for the arm and shoulder strength of most workers.

Other things like heat, reaching, and bending make the job more difficult.

Some of the tools need larger and different kinds of grips.

What Managers Can Do

Change the job so that the dross can be moved to the chiller without lifting.

Get a chiller that has an edge lower than the zinc pot so the dross can be lowered into the chiller.

Find out how much skimming is needed to keep the machine snout from clogging.

What the Employees Can Do

Pull the spoon pan to the edge of the pivot point before raising the spoon out of the bath.

Skim only as much as is needed to keep the machine running to reduce reaching and bending.

Try to pace yourself while skimming to avoid fatigue.

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513/841-4252 and ask for HETA Report #2000-0316-2811

National Institute for Occupational Safety and Health
NIOSH

Health Hazard Evaluation Report 2000-0316-2811
Material Sciences Corporation
Pinole Point Steel
Richmond, California
October 2000

Daniel J. Habes

SUMMARY

On June 7, 2000, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from the Director of Environmental Safety and Health at Material Sciences Corporation, Elk Grove Village, Illinois. The request stated that workers at the company's Pinole Point Steel facility, located in Richmond, California, were experiencing strain to the lower back and arms while performing a zinc pot skimming operation. The request also stated that over the years there had been two confirmed cases of carpal tunnel syndrome among workers performing the job.

A NIOSH ergonomist evaluated one worker performing the pot skimming operation on June 27 and 28, 2000. A biomechanical and lifting analysis indicated that the forces and moments at the joints on the left side of the body, particularly at the shoulder, and at the low back from lifting a long-handled spoon of dross weighing 40 pounds, were high and beyond the capabilities of all but the strongest of workers.

One worker had recently injured his left wrist while performing the pot skimming task, and historically there have been many complaints by workers of strain to the arms and lower back.

The results of the NIOSH investigation indicate that the unassisted lifting of dross while skimming the zinc pot is beyond the capability of most workers. Heat and awkward postures of the shoulder and trunk while skimming and performing other essential job activities increase the biomechanical and physical load on the worker. Recommendations for reducing the physical demands of the pot skimming task are included in this report.

Keywords: SIC 3479 (Galvanizing of iron and steel and end formed products, for the trade) ergonomics, carpal tunnel syndrome, pot skimming, lifting dross

TABLE OF CONTENTS

Preface ii

Acknowledgments and Availability of Report ii

Highlights of the HHE Report iii

Summary iv

Introduction 1

Background 1
Process and Job Description 1

Methods 2

Evaluation Criteria 2

Results 3
3-D Static Strength Model 3
Revised NIOSH Lifting Equation (NLE) 4
Working Postures 4

Discussion 4

Conclusions 6

Recommendations 6

References 6

Appendix 10

INTRODUCTION

On June 7, 2000, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) from the Director of Environmental Safety and Health at Material Sciences Corporation, Elk Grove Village, Illinois. The request stated that workers at the company's Pinole Point Steel facility, located in Richmond, California, were experiencing strain to the lower back and arms while performing a zinc pot skimming operation. The request also stated that over the years there had been two confirmed cases of carpal tunnel syndrome among workers performing the job.

On June 27 and 28, 2000, a NIOSH representative visited the Richmond, California, plant. An opening conference was conducted, and the pot skimming operation was viewed. During the conduct of the evaluation, videotapes were taken of the operation, workplace components and tools were photographed and measured, and workers were informally interviewed about the work process. A closing conference was held on June 28, 2000.

BACKGROUND

The Pinole Point plant of Material Sciences Corporation converts rolls of cold-rolled steel into rolls of galvanized and/or painted steel. These processes are mainly automated, but in the galvanizing department there is one essential job that is performed manually, namely the zinc pot skimming operation. In April 2000, an assistant operator in the galvanizing department reported pain in his left wrist from performing this operation. The injury was later diagnosed as carpal tunnel syndrome. Historically, there have been two confirmed carpal tunnel cases and numerous complaints of strain to the lower back and arms among employees skimming the zinc pot.

The company was aware that California has an ergonomics standard. Provisions of this standard would require implementation of a program designed to minimize the future occurrence of repetitive motion injuries (RMIs) if another employee were to sustain an injury to the same part of the body while performing the pot skimming task. This program would have to include evaluation of the job's ergonomic stress factors; implementation of work process changes, tool modifications, or use of other administrative and engineering methodologies to control worker exposures; and training of workers to avoid future injury. The Company decided it would be best for employee safety and health if the job were evaluated before another injury were to occur, so they submitted the HHE request to NIOSH.

Process and Job Description

The Pinole Point Steel plant receives coils of cold-rolled steel from a variety of suppliers. The coils are mounted on a large spindle and proceed through a variety of continuous operations in which the steel is cleaned, annealed, cooled, and then galvanized. The galvanized finish is applied by passing the unraveled roll of steel through a zinc bath heated to 850 °F. The thickness of the coating is controlled by jets of air blown onto the steel as it exits the bath. The intensity of the air flow is a function of the desired thickness of the coating and the speed at which the steel runs through the zinc, which can vary from 90-600 feet/minute.

The air blowing on the zinc forms a thick waste product called dross that floats on the surface of the zinc bath. When the dross accumulates to the point where it begins to collect around the passageway of the steel, called the snout, it must be removed from the zinc bath. Workers have a variety of long-handled blunt tools and spades to free dross from the snout, but the main tool used is a long handled shovel or "spoon" to lift the dross out of the bath and into a container called the chiller. The spoon pans are either rectangular or round in shape, shafts vary in length from 57-62 inches, and have either a T- or V-shaped handle at the end of the shaft. The typical weight of a spoon of either type is about 5 pounds. The diameter of the shaft and T-handles at the end of the tool varied from 3/4 inch to 1 1/4 inches. The pan of the rectangular spoons varied in length from 11-13 inches, but all were about 10 inches wide and 1 inch deep. The round spoons, which were a new design purchased soon after the worker was injured, were either 10 or 12 inches in diameter and 2 inches and 1 inch deep, respectively. Each type of spoon had holes in the pan to allow for the useable zinc to drain back into the bath after dross had been raised out of the bath.

When skimming the dross, the worker first clears the snout with one or more of the long handled specialty tools, and then diverts the dross to a corner of the zinc bath using the spoon of his choice. The motion is similar to skimming leaves from a swimming pool. A dam placed in the bath near the corner facilitates the accumulation of the dross at the corner. Next, the worker reaches over the sill of the zinc bath (22 inches high) and dips the spoon in the bath to collect the dross. The loaded spoon pan is held in place for a few seconds to allow the useable zinc to drain back into the bath and then the remaining dross is transferred to a chiller located behind and to the left of the worker. The edge of the chiller is 24 inches off the floor, and the lateral distance from the chiller to the zinc bath is about 48 inches. At the time of the NIOSH visit, the workers were using an inverted metal container placed on the sill of the zinc bath as a pivot point for the shovel, which facilitated the removal of dross from the bath. The metal container used as the pivot was actually a small chiller that is no longer used at the plant. Workers wear long sleeves, hard hat with full face mask, and heavy gloves while skimming the pot.

The number of spoonfuls of dross that must be scooped out of the bath per skim depends on how much dross was allowed to accumulate, and the frequency at which the dross removal takes place varies with the speed of the moving coils. At 100 feet/minute, the dross is skimmed once or twice per day, and at speeds of 500 feet/minute, which is near the maximum for the process, the dross is skimmed about once per hour. Most steel produced by the company is run at speeds close to the maximum.

Other activities performed by the assistant operator in the galvanizing department are monitoring the performance of the air knives, adding blocks of zinc and other materials to the bath as the contents are used, and making sure that no dross accumulates around the snout of the galvanizing machine.

METHODS

The main focus of this HHE was to evaluate the physical demands of the pot skimming task, particularly at the moment the loaded spoon is lifted off the pivot point and transferred to the chiller. To estimate the load in each hand when the lifting took place, a spoonful of dross was collected and weighed, and the distance each hand was from the center of the spoon pan was measured and recorded. The height to which the loaded spoon was lifted and the distance it was transferred was also measured. Video tapes were taken while workers performed the job so that the number of spoonfuls of dross removed per skim could be determined. The videotapes also allowed for quantification of body postures and hand positions while the task was performed.

EVALUATION CRITERIA

Overexertion injuries, such as low back pain, tendinitis, and carpal tunnel syndrome, are often associated with job tasks that include: (1) repetitive, stereotyped movement about the joints; (2) forceful manual exertions; (3) lifting; (4) awkward and/or static work postures; (5) direct pressure on nerves and soft tissues; (6) work in cold environments; or (7) exposure to whole–body or segmental vibration.[1,2,3,4] The risk of injury appears to increase as the intensity and duration of exposure to these factors increases and recovery time is reduced.[5] Although personal factors (e.g., age, gender, weight, fitness) may affect an individual's susceptibility to overexertion injuries/disorders, studies conducted in high–risk industries show that the risk associated with personal factors is small compared to that associated with occupational exposures.[6]

In all cases, the preferred method for preventing/controlling work–related musculoskeletal disorders (WMSDs) is to design jobs, workstations, tools, and other equipment to match the physiological, anatomical, and psychological characteristics and capabilities of the worker. Under these conditions, exposures to task factors considered potentially hazardous will be reduced or eliminated.

The following two criteria were used to evaluate the pot skimming task at the Pinole Point Steel plant: 1) the biomechanical outputs obtained from the Michigan 3-Dimensional Static Strength Prediction Program™ [7] and; 2) recommendations for acceptable lifting weights as determined by the NIOSH Revised Lifting Equation.[8] The Michigan 3-Dimensional Static Strength Prediction Program™ (3DSSPP) is a computerized model which can be used to evaluate the physical demands of a prescribed job. Typical inputs to the model are the magnitude and direction of forces at the hands, angles of body segments, and anthropometric selection such as gender and population size percentiles. The model outputs moments at the joints of the body and percentages of the chosen population able to sustain the inputted loads. The 3DSSPP can be used to evaluate the biomechanical demands of an existing task or to predict the physical demands of a task that is being designed or modified.

The NIOSH lifting equation (NLE) is a tool for assessing the physical demands of two-handed lifting tasks. A full description of the components of the NLE is provided in the Appendix. In brief, the equation provides a recommended weight limit (RWL) and a lifting index (LI) for a lifting task, given certain lifting conditions. The RWL is the weight that can be handled safely by almost all healthy workers in similar circumstances. The LI is the ratio of the actual load lifted to the RWL. Lifting tasks with a LI $\leq$ 1.0 pose little risk of low back injury for the majority of workers. Tasks with a LI > 1.0 may place an increasing number of individuals at risk of low back injury. The consensus opinion of an expert panel, described in the NLE report, is that tasks with a LI > 3.0 pose a risk of back injury for most workers.

RESULTS

3-D Static Strength Model

Figures 1 and 2 summarize the results of applying the 3DSSPP model to the pot skimming task. The forces and moments indicated in these figures pertain to the instant when the loaded spoon is lifted off the pivot point. The load at the left hand was 80 pounds and the load at the right hand was 10 pounds. The load at the left hand was determined by weighing one spoonful of dross (40 pounds) and noting the position of the left hand on the spoon handle while the worker was in position to lift (24 inches from the center of the pan). The worker used a spoon with a 12 inch diameter pan. Ten pounds was chosen as the load at the right hand to account for the weight of the tool and the nominal amount of effort needed to balance the load with the right hand. Workers who have performed the task indicated that most of the effort is sustained by the left hand, and this was verified by the NIOSH investigator who tried the job several times.

The results indicate that for the 50^{th} percentile male, fewer than 10 percent of the population have the strength to sustain the resultant moment at the ankle, knee, hip, elbow, and shoulder for the left side of the body. Moreover, the model estimates that 0 percent of the population has the left shoulder strength to perform the task safely.

Revised NIOSH Lifting Equation (NLE)

The inputs to the NLE were 45 pounds weight, horizontal location of the load at 25 inches from the body, initial and final vertical location of the load at 20 and 30 inches, respectively, asymmetric angle equal to 45°, good coupling and occasional lifting frequency. The NLE defines "occasional lifting" as equal to or fewer than one lift per five minutes. Videotape analysis indicated that the worker made about 2 lifts per minute during the lifting period of approximately 10 minutes per skim, but that the interval between successive skims was long enough to classify the job as occasional lifting. Given these task variable inputs, the calculated Lifting Index was 2.8.

Working Postures

Lifting the loaded spoon from the bath to the chiller is the most stressful part of the job, but the video analysis indicated that the workers also perform a variety of stressful body postures while performing other aspects of the skimming job. Long reaches are required to place and remove the dam, long reaches and forward bending of the trunk occur frequently while gathering the dross, and long reaches and repetitive motions involving the shoulders are required while using the long-handled tool to clear dross from the snout.

DISCUSSION

The 3DSSPP analysis performed on the pot skimming job indicates that the biomechanical demands on the musculoskeletal system are beyond the capabilities of most workers. This analysis was limited in that only one worker was studied, and the job was not seen under typical working conditions. Three separate skims were analyzed, but the galvanizing speeds during those times were at 375 or fewer feet/minute. The most common product produced by the company runs at 520 feet/minute, which would require more frequent skims with possibly heavier loads of dross in the spoon, to keep up with the speed of the machine. The typical working conditions were not observed because on both days of the evaluation, the plant shut down in the early afternoon due to electrical shortages experienced by the local community. Higher machine speeds were scheduled but not observed by NIOSH due to these unexpected plant shut downs. Nonetheless, the results of the 3DSSPP analysis indicate that the job would possibly be more stressful to the worker during the more common production conditions.

A lifting index of 2.8 indicates that the job presents an elevated risk of injury to the back for most workers, and is close to a lifting index of 3.0, which is considered a hazardous lifting condition for all but the strongest of workers. However, the NIOSH lifting equation is most suited for lifting tasks in which the load is held between the two hands. Assuming a two handed lift of this type, the largest horizontal distance of the load from the body that can be used in the calculation is 25 inches. A load held further from the body is considered to present problems with balance. However, in the case of lifting the spoon, the major part of the load is beyond the hands, but at a distance approaching 40 inches from the body depending on which spoon is used and how it is lifted. Therefore, in this case, the NIOSH lifting equation tends to underestimate the actual hazard of the lifting portion of the job due to this limitation in horizontal load location that can be inputted to the model.

The videotape analysis also indicated that there are some awkward and fatiguing postures and movements associated with the non-lifting portions of the skimming job. The heat given off by the zinc bath is also fatiguing to the worker, neither of which are considered by the 3DSSPP or NLE analyses.

The loaded spoon is lifted because the sill height of the chiller is greater than the height needed to clear the spoon from the zinc bath. The additional distance the spoon must be raised is small, but it still requires the worker to lift the long-handled spoon off the pivot and to the chiller for dumping. If the chiller were at the same height or lower, the load could be transferred to the chiller or poured on a slide or ramp leading to the chiller and the worker would not have to bear the biomechanical load associated with the lift. As the job is performed now, the load is dumped into the chiller by rotating the spoon 90°, requiring a flexion or extension of the left wrist (depending on how the left hand is positioned on the shaft of the tool) and a rotation of the right forearm. The left hand bears most of the weight, and flexion/extension of the wrist is a risk factor for carpal tunnel syndrome, so it is not surprising that the most recent injury sustained by a worker occurred to the left wrist. Not having to make wrist extension or flexion movements while supporting a large weight would likely reduce the chances of a similar injury.

The inverted small chiller serves as an effective pivot point, allowing leverage to be used to raise the loaded spoon out of the bath. If it were higher, as wide as the sill of the zinc bath, and long enough to extend to the chiller, the spoon could be raised as usual using the front edge as the pivot, then slid towards the worker out of the confines of the bath, and then slid over to the chiller and dumped as usual, but without the worker supporting any weight. The top surface of the modified pivot could be equipped with skate wheels or rollers as in assembly line conveyors, or a ball transfer table top to allow for the easy movement of the spoon. The spoon shaft could also be mounted on a ball-type swivel fixture so that the spoon can be moved in and out of the bath, and rotated toward the chiller to allow dumping of its contents directly into the chiller, or dropped onto a slide which leads to the chiller. The main concept in all redesign approaches would be to transfer the load, not lift it, by using leverage to raise the spoon and gravity to dump the dross. A further refinement in the process method would be to add a grip to increase the diameter of the shaft to about 1.5 inches where the worker couples the left hand and at the T-handle where the right hand is placed. This diameter has been shown to optimize the trade-off between force exertion and fatigue when using hand tools.[9] Moreover, wrist extension and flexion postures of the left wrist while pouring the dross could be avoided by mounting a T- or D-handle perpendicular to the shaft at the position of the left hand. This would allow a palm down left hand orientation and the load could be dumped by rotating the forearm while maintaining the wrist in a neutral position. An auxiliary handle would also raise the position of the left hand and reduce trunk flexion (bending over) when dipping the spoon into the zinc bath.

Regarding leverage, it is important to position the spoon pan as close to the pivot point as possible and practical before raising the dross out of the zinc bath. This technique maximizes the worker's mechanical advantage when removing the dross. With a 60 inch handle, and a 12 inch diameter spoon holding a load of 40 pounds, the worker would have to exert 4 pounds of force at the end of the tool to lift the dross out of the bath. From a standing position, an average man is able to exert about 45 pounds of downward force on a T-handle.[10]

An issue in pot skimming is the extent to which the bath needs to be skimmed each time. The purpose of the skim is to ensure that the snout of the galvanizing machine does not clog during the process. Some dross can remain in the bath and not affect the speed or quality of the operation, although at some point it must be removed. This flexibility could allow the machine assistant operator to pace himself during the day, particularly when the line is running fast and more frequent skims are required, and other run-time activities occur more frequently such as adding zinc and other metals to the bath. During the observed pot skims, the worker tended to clear the zinc bath completely, removing dross from hard-to-reach corners far from the snout of the galvanizing machine. This practice adds to the postural load of the operation because the worker has to bend the trunk and fully extend the arms to reach some of the obscure areas of the bath. These areas of the bath could be cleared less often than the rest of the zinc bath, which would give the worker more rest between skims and more time to perform other essential work tasks.

CONCLUSIONS

1. Lifting the spoon loaded with dross from the bath to the chiller is a task which imposes high biomechanical forces on the body and is unsafe for all but the strongest of workers.

2. Other postural and environmental factors not considered by the methods used to evaluate the pot skimming task, such as long reaches, trunk bending, and heat may add further risk of injury to the worker.

3. The task can be performed within the capabilities of most workers if the load is transferred to the chiller and not lifted by the worker.

4. Redesign of the tool handles and grips can further reduce the physical demands of the task.

RECOMMENDATIONS

1. Redesign the pot skimming task so that the dross can be transferred without being lifted and poured into the chiller. Gravity and leverage should be used in conjunction with swivelling fixtures or conveyors and slides to transport the dross to the chiller.

2. Place grips on all tools to enlarge the diameter to 1.5 inches where the hands couple. Add a D- or T-handle to the shaft of the spoon, where the left hand grips the tool, to eliminate wrist extension and flexion when dumping the dross, and trunk flexion when raising the spoon from the zinc bath.

3. Position the spoon shaft on the pivot point as close as possible to the pan before raising the dross out of the zinc bath.

4. Minimize the frequency of stressful postures such as long reaches, shoulder rotations, and trunk bending that occur during the skimming operation by determining the minimum amount of skimming that is needed to ensure the smooth operation of the galvanizing equipment and the quality of the finished steel

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Table 1

Frequency Multiplier (FM) for NIOSH Lifting Equation

Frequency Lifts/min	Work Duration					
	≤ 1 Hour		≤ 2 Hours		≤ 8 Hours	
	V† < 75	V ≥ 75	V < 75	V ≥ 75	V < 75	V ≥ 75
0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

†Values of V (vertical location of the load) are in centimeters (cm); 75 cm = 30 in.

Table 2

Coupling Multiplier (CM) for NIOSH Lifting Equation

Couplings	V< 75 cm (30 in)	V $\geq$ 75 cm (30 in)
	Coupling Multipliers	
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

APPENDIX

The Factors Comprising the NIOSH Revised Lifting Equation

Calculation for Recommended Weight Limit

RWL = LC * HM * VM * DM * AM * FM * CM
(* indicates multiplication.)

Recommended Weight Limit

Component			Metric	U.S. Customary
LC	=	Load Constant	23 kg	51 lbs
HM	=	Horizontal Multiplier	(25/H)	(10/H)
VM	=	Vertical Multiplier	(1-(.003|V-75|))	(1-(.0075|V-30|))
DM	=	Distance Multiplier	(.82+(4.5/D))	(.82+(1.8/D))
AM	=	Asymmetric Multiplier	(1-(.0032A))	(1-(.0032A))
FM	=	Frequency Multiplier	(From Table 1)	
CM	=	Coupling Multiplier	(From Table 2)	

Where:

H = Horizontal location of hands from midpoint between the ankles.
Measure at the origin and the destination of the lift (cm or in).

V = Vertical location of the hands from the floor.
Measure at the origin and destination of the lift (cm or in).

D = Vertical travel distance between the origin and the destination of the lift (cm or in).

A = Angle of asymmetry – angular displacement of the load from the sagittal plane.
Measure at the origin and destination of the lift (degrees).

F = Average frequency rate of lifting measured in lifts/min.
Duration is defined to be: < 1 hour; < 2 hours; or < 8 hours assuming appropriate recovery allowances.

Figure 1: Analysis Summary for the Michigan 3DSSPP Model

Analyst: **Daniel Habes**

Location: **Pinole Point Steel, Richmond, California**

Job Task: **Pot Skimming**

Sex: **Male**

Analysis Summary

Anthropometry

Height = 69.7 inches

Weight = 165.6 pounds

Force on Hand	Right	Left	
Magnitude (pounds)	10	80	
Components (pounds)			
X axis	0.0	0.0	
Y axis	0.0	0.0	
Z axis	10.0	-80.1	

L5/S1 Disc Compression Force: 964 ± 78 pounds

Estimated Ligament Strain (%): 13.5

Percent of Population with Sufficient Strength Capablility

Elbow:	6%
Shoulder:	0%
Torso:	61%
Hip:	5%
Knee:	5%
Ankle:	10%

Data obtained from: 3DSSPP (3.0), Copyright 1995, The University of Michigan, All Rights Reserved

Figure 2: Resultant Moments About Hinges of Joint Movement

Body Area	Resultant Moment (Nm)	Right Side of Body			
		Muscle Effect	Population Strengths		
			Mean (Nm)	SD (Nm)	% Cap
Elbow Flexion/Extension	3	Extension	40	8	100
Shoulder					
Humeral rotation	8	Medial	17	4	98
Rotation backward/forward	0	--	--	--	100
Abduction/adduction	8	Adduction	79	25	99
Trunk					
Flexion/Extension	-327	Extension	360	113	61
Lateral bending	-155	Right	928	276	99
Rotation	-134	Left	345	56	100
Hip Flexion/Extension	10	Flexion	216	59	100
Knee	0	--	--	--	100
Ankle	0	--	--	--	100
		Left Side of Body			
Elbow Flexion/Extension	-75	Flexion	54	13	6
Shoulder					
Humeral rotation	-5	Lateral	42	9	100
Rotation backward/forward	42	Backward	67	19	89
Abduction/adduction	-165	Abduction	75	19	0
Trunk					
Flexion/Extension	-327	Extension	360	113	61
Lateral bending	-155	Right	928	276	99
Rotation	-134	Left	345	56	100
Hip Flexion/Extension	-337	Extension	206	83	5
Knee	-195	Flexion	132	39	5
Ankle	-195	Extension	139	46	10

Nm = Newton-meters SD = standard deviation %Cap = percent of population capable

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For Information on Other
Occupational Safety and Health Concerns

Call NIOSH at:
1–800–35–NIOSH (356–4674)
or visit the NIOSH Web site at:
www.cdc.gov/niosh

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